Senior Thesis

Significance of an occurrence of an Upper Ordovician zone index conodont, *Amorphognathus ordovicicus,* in the Richmondian of Southeastern Indiana

by
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Approved by:

Dr. Stig M. Bergström

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My continuing education would not have been possible without the unwavering support of wife Cynthia Conlon MacKenzie. Many, many thanks are in order.

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Abstract

The focus of this study was the acquisition of elements of the genus *Amorphognathus,* a biostratigraphically important conodont genus, that would allow clear and positive determination of species and clarify the North Atlantic Province conodont biozonation of the Upper Maysvillian - Lower Richmondian stages of the Cincinnatian Series. Samples were collected from three stratigraphically well-classified outcrops around Brookville, Indiana in an attempt to sample a 'deeper water' facies of the Cincinnatian (Upper Ordovician) in its type region. Fifteen transitional elements of *Amorphognathus ordovicicus- A. superbus* and three unquestionable *A. ordovicicus* elements have thus far been isolated from two of these sections. These specimens are the first recovered from the type Cincinnatian that can be identified with certainty as *A. ordovicicus,* which is a zonal index species. Previous studies have shown *A. superbus* to be present in the Miamitown Shale. Specimens of *A. superbus* have also been recovered from a core at an interval that corresponds to approximately thirty meters below the studied section. Based on the presence of the transitional forms, as well as typical specimens of *A. ordovicicus*, near the Waynesville-Arnheim contact, it appears that the *A. ordovicicus - A. superbus* Atlantic Province Conodont Zone boundary lies within the uppermost Arnheim Formation. The stratigraphic position of this boundary compliments macrofossil evidence suggesting that the typical Richmondian shelly fauna appears within the Arnheim Formation. This enables, for the first time, not only higher resolution correlation with sucessions in Baltoscandia and Great Britain but also this will clarify the depositional history of the Upper Ordovician in North America.

INTRODUCTION

The Type Cincinnatian of the Cincinnati Region

Edward Orton (1873) wrote:

> *"The fossils of the group are so very abundant, and so often so beautifully preserved, that they cannot fail to attract the attention of even the most thoughtless observer."*

The group referred to by Orton (1873) was the 'Cincinnati Group' as proposed by Meek and Worthen (1865). These strata in the Cincinnati region have some of the most abundant and well preserved Upper Ordovician fossil faunas known anywhere in the world, and these faunas have been subjected to numerous studies for more than 200 years. As early as 1887 the Cincinnatian was being considered the type area for the North American Upper Ordovician when Winchell and Ulrich wrote:

> *"There is no other locality on the continent that deserves so well to be considered the typical locality for the series of strata in question as the region about Cincinnati, Ohio."*

The term Cincinnatian as a designation of the North American Upper Ordovician was introduced by Clarke and Schuchert (1899). The Cincinnatian rocks crop out over 51,800 square miles in the tri-state region of Ohio, Kentucky and Indiana (Figure 1). Impressive sections through these highly fossiliferous strata ring the City of Cincinnati in highway and stream cuts for miles in all directions. Numerous authors have worked on the stratigraphy and paleontology of the rocks in the Cincinnati region since their initial descriptions in the early 1800's and research on the correlation of the Cincinnatian strata with successions elsewhere in the world continues.

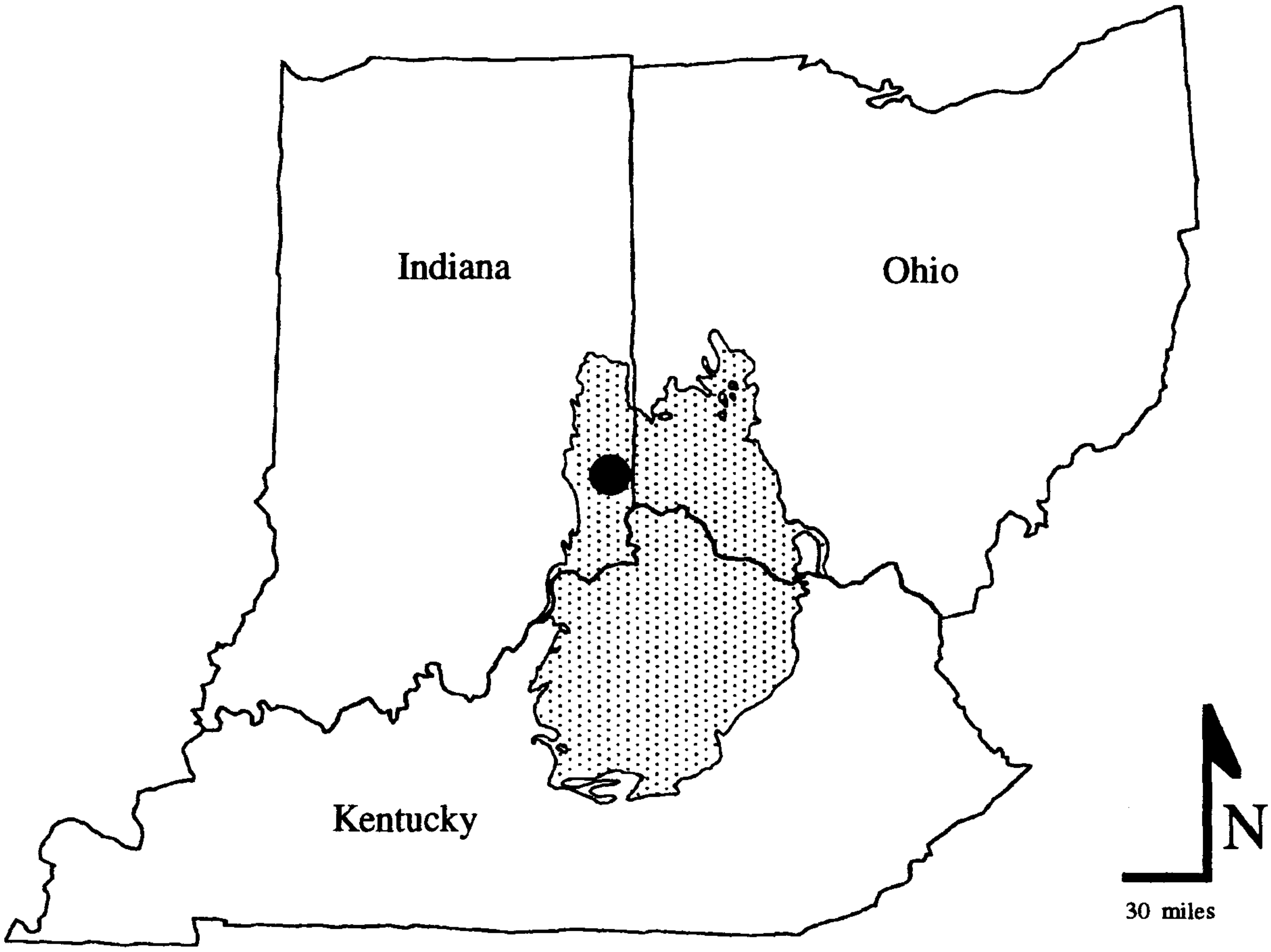

Figure 1: Ordovician outcrop area in the Cincinnati region. Spot indicates study area. Modified from Kohut and Sweet (1968).

The Importance of Precise Stratigraphy

It is necessary to establish precise biostratigraphy, including well defined zones and zonal boundaries based on different faunal groups in order to understand local and regional events in Earth's history. Problems that have historically plagued stratigraphic investigations include diachronous rock units, lack of faunal diversity and abundance, poor preservation of fossils, facies variations within rock units, poorly understood taxonomy of fossil groups, unrefined stratigraphic methods, and regional faunal provincialism. By constructing a mosaic of biostratigraphic zones based on various fossil groups we are able to reconcile provincial, facies, and classification problems and construct precise correlations throughout the world. The Cincinnati region provides stratigraphers the unique opportunity to utilize with relative ease a number of biostratigraphic frameworks. The outstanding exposures, as well as the very fossiliferous nature of the strata, in the Cincinnati region permit unparalled studies of virtually all Upper Ordovician fossil groups and use of various stratigraphic approaches. For instance, recently, as an outgrowth of the well known shoaling cycles of the Cincinnatian (Schumacher, 1993), sequence stratigraphy has been applied to the type Cincinnatian Series (Holland, 1993) (Figure 2).

Conodonts, provincialism and the role of *Amorphognathus*

Less than twenty years after the first published description of conodonts by C.H. Pander (1856), these fossils were recognized in the Upper Ordovician of North America by J.S. Newberry (1875). A couple of years later Hinde (1879) figured the first conodonts of the Cincinnatian and James (1884) figured the first conodonts of the Cincinnati Region. Conodonts have since been established as one of the best guide fossils in Ordovician rocks worldwide. Their abundance and rapid evolution make them very useful for precise local and regional correlations. However, like most other Ordovician fossils, most conodonts are provincial in their distribution (Sweet et al., 1959).

Provincialism is a term used for the phenomenon that distinct faunas tend to occupy

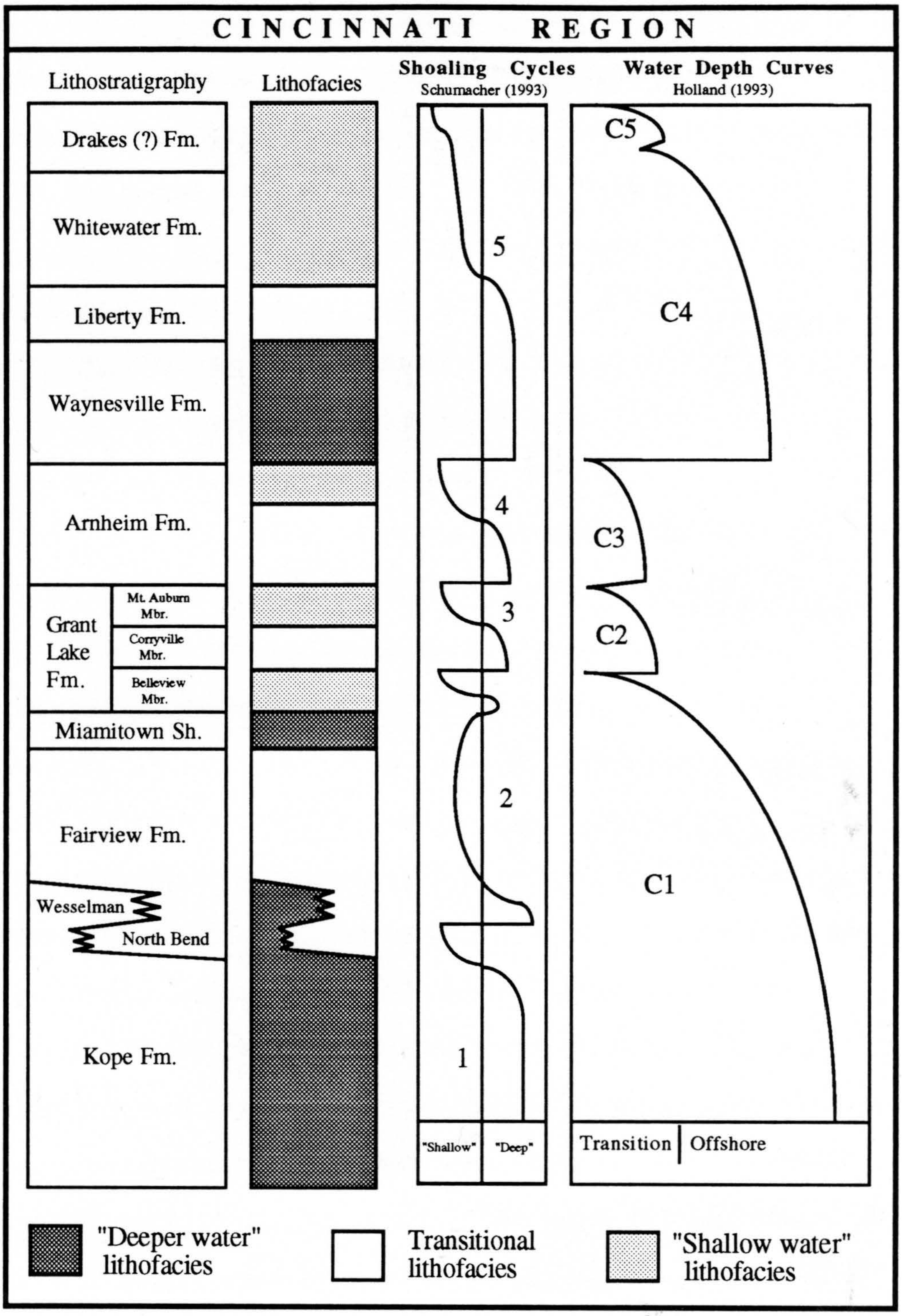

Figure 2: Recent implications of Cincinnatian lithofacies and water depth, after Schumacher (1993) and Holland (1993).

geographically distinct regions during a particular period of time. The distribution of provinces is a result of physical (i.e. geographic and geomorphic) and environmental (i.e. water temperature) barriers that inhibit migration of faunas between regions. Provincialism of Late Ordovician conodonts has been described by numerous authors (Sweet, 1959; Barnes et al., 1973; Bergström, 1973, 1990; Sweet & Bergström, 1974,1984; Dzik, 1983) and remains a major obstacle in the correlation of North American and European Upper Ordovician strata (Figure 3).

Bergström (1971) established a biostratigraphic zonal scheme for the Middle and Upper Ordovician of the European or North Atlantic Province (Figure 4), and Sweet et al. (1971) introduced a succession of conodont faunas for the North American Midcontinent Province (Figure 5). Sweet has since developed a framework of reference sections in an attempt to better resolve the stratigraphy of the North American Midcontinent (Sweet, 1984). This framework is developed by utilizing the graphic correlation concept (Miller, 1977; Sweet, 1984). However, striking provincialism complicates correlation between these biostratigraphic schemes. In the North Atlantic Province, species of the genus *Amorphognathus* Branson and Mehl 1933 are used as indices of the Upper Ordovician zones. This genus is especially important in that it occurs in both the North Atlantic and Midcontinent Provinces, although it is less common in the latter province which includes the Cincinnati region. Bergström (1971) noted that post-Edenian specimens of *Amorphognathus* from the type Cincinnatian were too incomplete to identify to species with any certainty. As a result, precise correlation of the Upper Ordovician using this diagnostic genus between the European and North American standard successions has remained uncertain.

Recent investigations have begun to clarify the position of the boundary of various North Atlantic Province conodont zones in the Cincinnatian reference standard. Diagnostic elements of *Amorphognathus superbus* Rhodes 1953 have been isolated from the New

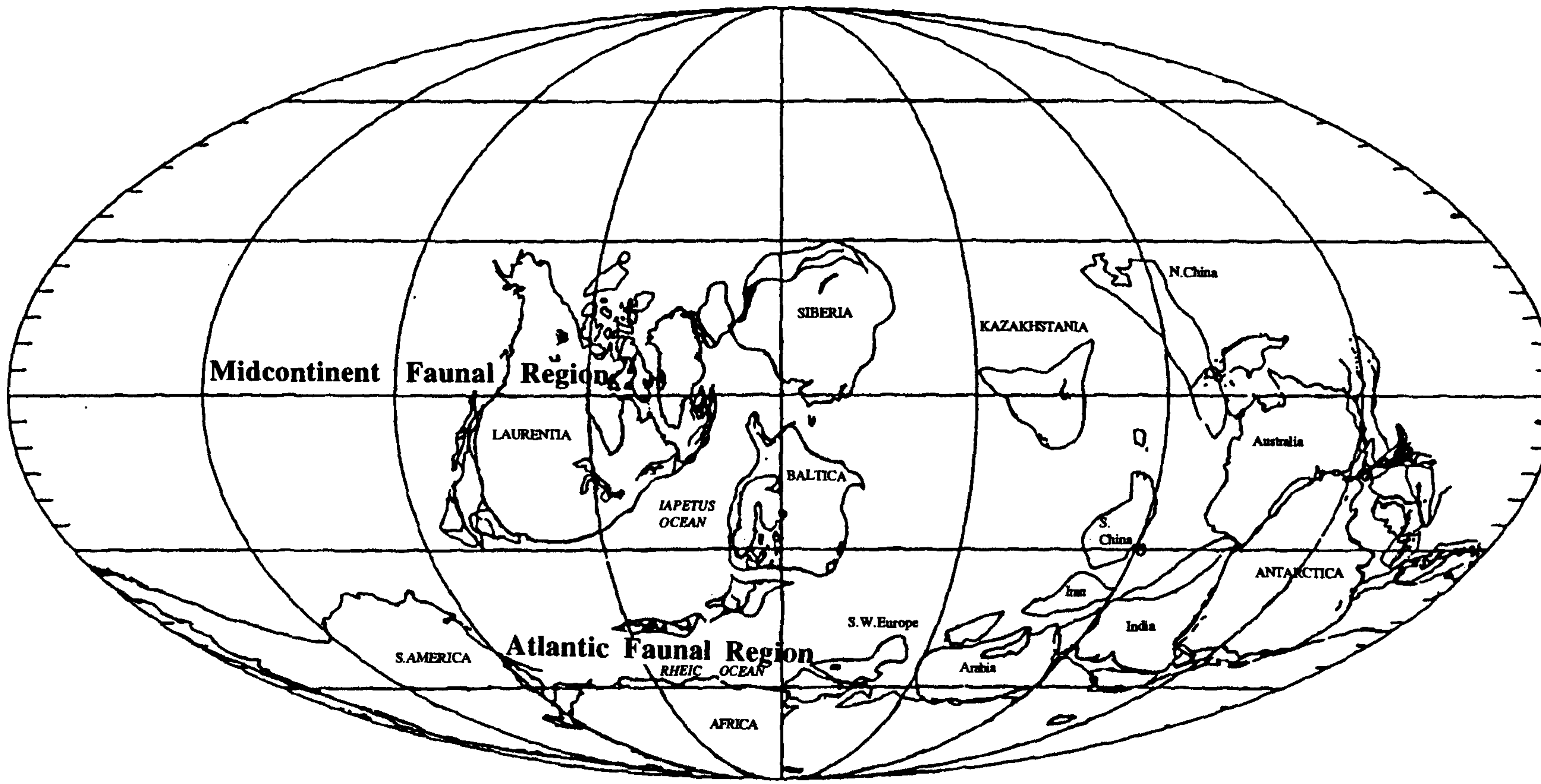

Figure 3: Upper Ordovician paleogeographic map with Midcontinent and Atlantic Faunal Regions annoted. Modified from Bergström (1990).

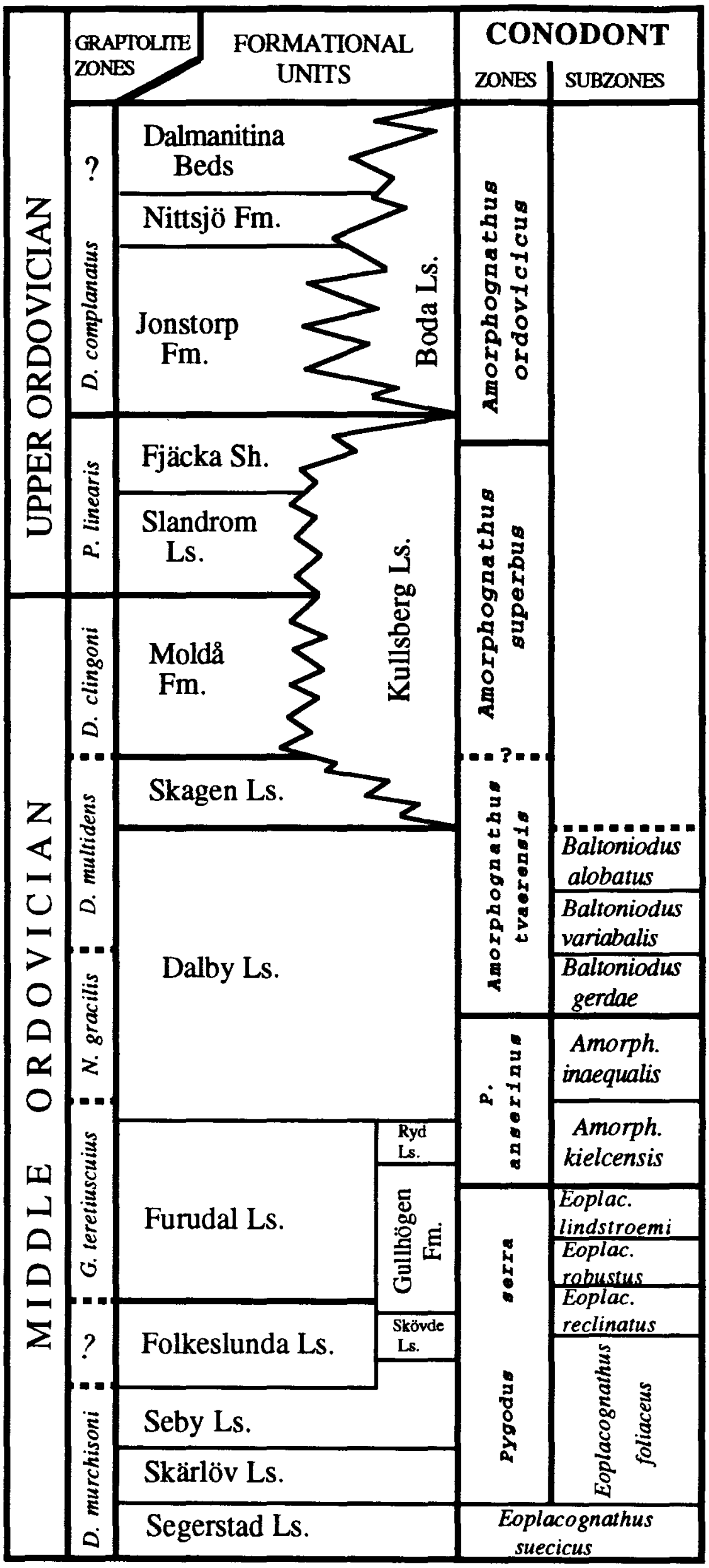

Figure 4: North Atlantic conodont zones and subzones from Bergström 1971 and 1983.

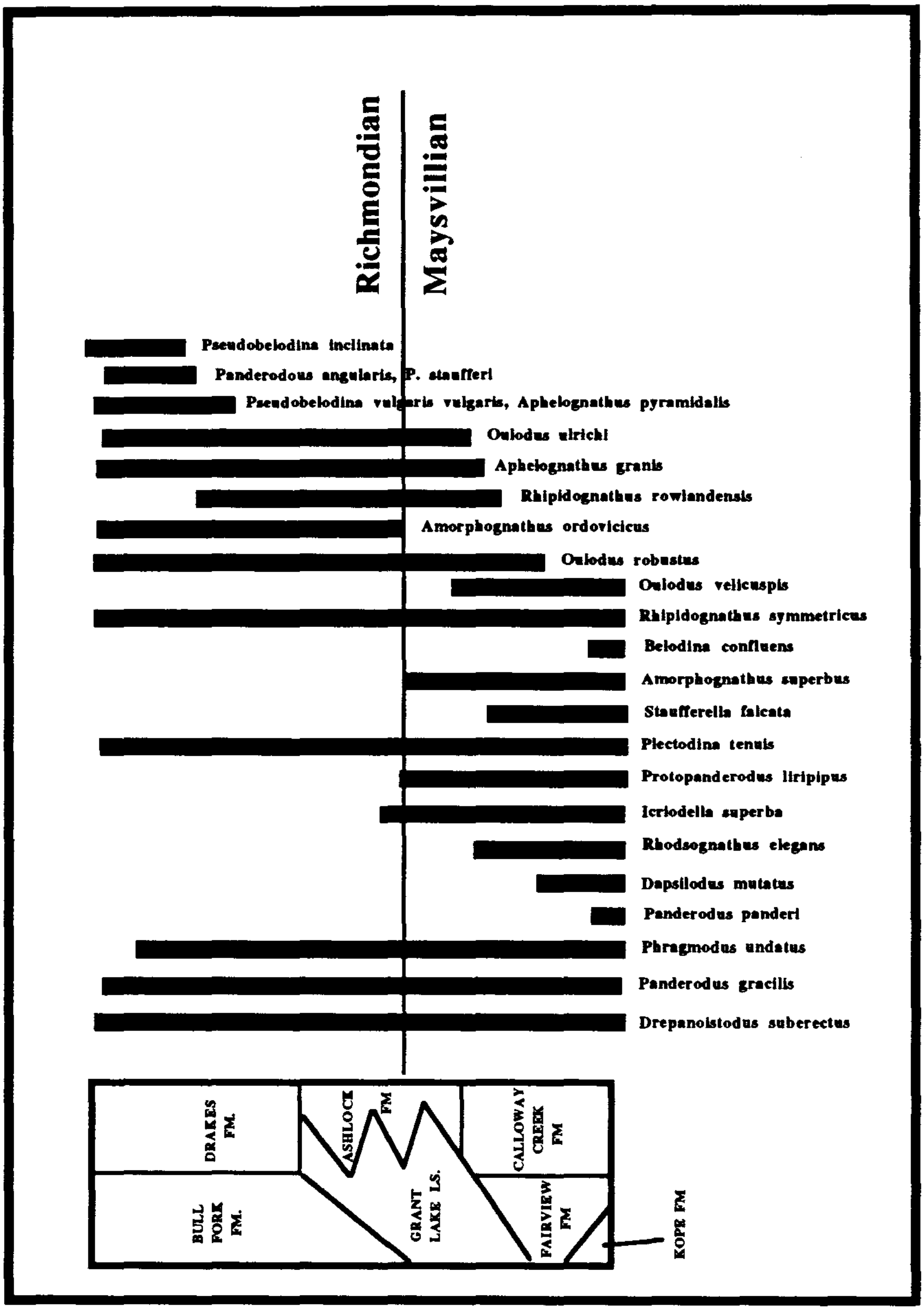

Figure 5: Ranges of important conodont species in the Midcontinent Upper Ordovician. Modified from Sweet (1984) with data from this study.

Point core (see Figure 7 for location). However, until this study, no diagnostic elements of the zonal index conodont *Amorphognathus ordovicicus* Branson and Mehl 1933 had been found anywhere in the Cincinnati Region. Based on comparison with the New York succession, the base of the *A. ordovicicus* Zone has been assumed to be somewhere in the lower Maysvillian (Sweet, 1979a). Izold (1989) demonstrated that the *A. ordovicicus* boundary was higher stratigraphically with the discovery of *A. superbus* in the middle-upper Maysvillian Miamitown Shale. The major goal of this study is to isolate unquestionable *A.ordovicicus* elements, and locate the level of the *A. superbus - A. ordovicicus* zonal boundary, in the type Cincinnatian. If successful, this would greatly improve correlation of the Cincinnatian with successions in not only North America but worldwide.

THE RICHMONDIAN STAGE

History

The term Richmond was proposed by Winchell and Ulrich in 1897 to replace Orton's (1873) Lebanon Beds, because Lebanon was preoccupied by Safford's (1851) use of the term for a division of the Middle Ordovician in Tennessee. Also, the exposures at Richmond, Indiana are far better than those near Lebanon. The Richmond Formation was said to overlie the Lorraine Group (Orton's Hill Quarry Beds) and is described by Winchell and Ulrich (1887) as a series of thin bedded shales and limestones reaching 350 feet thickness in southwestern Ohio and southeastern Indiana. Some subsequent authors (Nickles, 1902; Foerste, 1903) contested the thickness reported by Winchell and Ulrich (1887) as well as their contention that the best exposures were at Richmond, Indiana. Clark and Shuchert (1899) were the first workers to use the term Cincinnatian Period to define an interval of Late Ordovician time. At about the same time, the Richmond attained stage status along with the Eden and Maysville (Foerste 1903). In 1914, Shuchert and Barrell affirmed that the Cincinnatian could be seperated into three distict stratigraphic units. Wilmarth (1925), of the U.S. Geological Survey, officially recognized the Cincinnatian, with the Richmondian as the topmost unit, as defined by Winchell and Ulrich (1897) and Clark and Schuchert (1899).

Historically, there has been confusion and disagreement among researchers as well as among the state surveys of Ohio, Indiana and Kentucky as to the lithologic classification of the Cincinnatian. This has resulted in several formational classification schemes (Figure 6). Although the present study was conducted in Indiana, I use Ohio nomenclature as the Ohio formations are readily recognizable at the study localities. The Ohio nomenclature is also more detailed, descriptive, widely known, and historically significant than that currently in use by the Indiana Geological Survey (Figure 6).

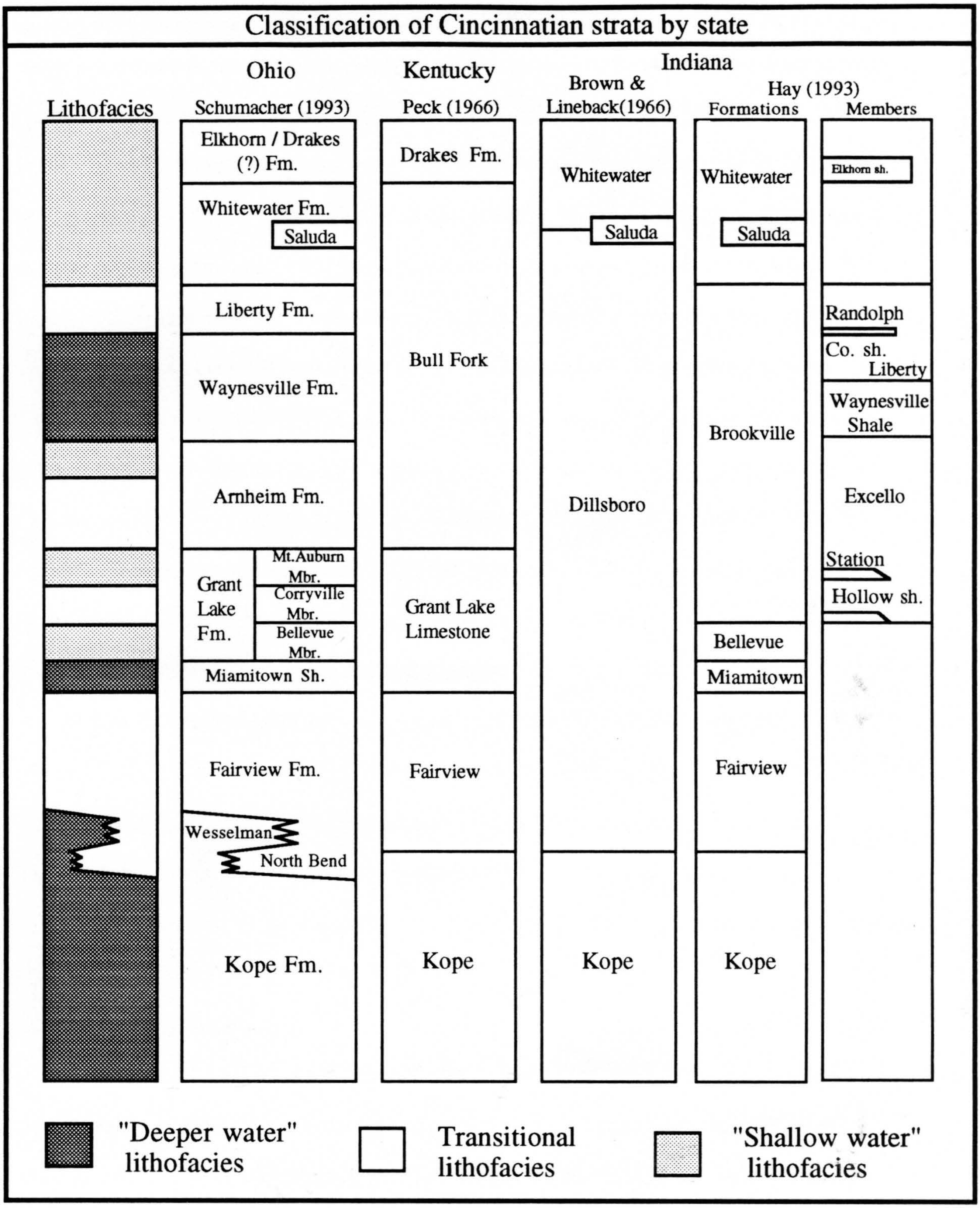

Figure 6: Upper Ordovician stratagraphic nomenclature comparison by state.

Arnheim Formation

Nickles (1902) initially termed what is now called the Arnheim the Warren Beds, and placed these in the Lorraine, which is a term used in New York State. Several authors concurred with this classification (Bassler, 1903; Nickles, 1903, 1905; Foerste 1903, 1904). Foerste (1905) found the term Warren preoccupied and proposed Arnheim as a replacement. Bassler (1906) then placed the Arnheim into the Richmond. Subsequent authors agreed (Cumings, 1907(1908); Willis, 1912; Foerste, 1909, 1912; Braun, 1916; Ulrich, 1913). Foerste (1910) divided the Arnheim into two divisions, the Sunset and the Oregonia. These divisions have been recognized off and on by numerous authors. Cummings and Galloway (1913) found the Arnheim faunas to be dominantly related to those of the Maysville, so they preferred to group the Arnheim with the Maysville. Cummings (1922) placed the Maysville - Richmond boundary at the Sunset - Oregonia contact. Subsequent authors have placed the Maysville - Richmond (Maysvillian - Richmondian) boundary at either the top or base of the Arnheim. Following the practice of the Ohio Geological Survey, the Arnheim is herein referred to the Richmondian.

The Arnheim Formation is as yet an informal formational designation, but will be officially recognized soon by the Ohio Survey (verbal communication, Schumacher, 1993). The Arnheim Formation typically consists of rubbly to planar bedded shaly limestones. The top two meters is a phosphate-rich grainstone with abundant gastropods and ostracodes. This bed is lithologically very characteristic and may be traced as a marker bed through a large part of Southwestern Ohio.

Waynesville Shale

Compared with surrounding units, the Waynesville Shale is characterized by a high content of the typical Cincinnatian blue clay-shale. It is characteristic enough lithologically to be recognized over large distances. Cummings (1901) divided the beds above the Arnheim into three faunal zones, the *Oniella (Dalmanella) meeki, Strophomena,* and

Rhynchotrema zones. Nickles (1903) proposed formational names for faunal zones in the same beds, Waynesville, being the *Oniella (Bythopora, Dalmanella) meeki* zone; Liberty, being the *Strophomena planumbona* zone; and Whitewater, being the *Homotrypa wortheni* zone. Subsequent workers (Foerste, 1909, 1910; Bassler, 1915; Braun, 1916; and others) divided the Waynesville into further subdivisions based on faunal criteria, but these have not been widely used.

THE BROOKVILLE, INDIANA AREA SECTIONS

Brookville area studied strata

The three sections studied are located near Brookville, in Franklin County, Indiana (see index map, Figure 7). Corresponding stratigraphic intervals in each section are lithologically quite similar, and the sections can be readily correlated with each other (Figure 8). The most prominent bed is the gastropod limestone that caps the Arnheim Formation, which is unconformably overlain by the Waynesville Shale. This prominent bed is used as the datum in this study.

Bon Well Hill

Located in the Whitcomb, Indiana Quadrangle, the Bon Well Hill section is a roadcut just north of the intersection of Indiana State Route 101 and Brookville Dam Road (Figure 9). The section begins in, and continues up, a drainage cut in the outcrop approximately 100 meters north of the intersection (Figure 10). It includes the topmost part of the Arnheim Formation and the lower part of the Waynesville Shale.

Brookville Dam Spillway

This section is located in the Brookville, Indiana Quadrangle, north-east side of the spillway, near the top of the lower portion of the spillway. This section was measured down from the prominent gastropod limestone bed that marks the top of Arnheim Formation (Figure 11) and includes the top few meters of the Arnheim Formation.

Southgate Hill

Located in the Cedar Grove, Indiana Quadrangle, this section is a huge roadcut on Indiana State Route 1, 1.9 miles south of its intersection with U.S. Route 52 at Cedar Grove (Figure 12). The section measured for this study begins on the west side of road near the base of the cut (Figure 13). It includes the topmost part of the Arnheim Formation, the entire Waynesville Shale, and most of the overlying Richmondian (Liberty, Whitewater, and Saluda Formations).

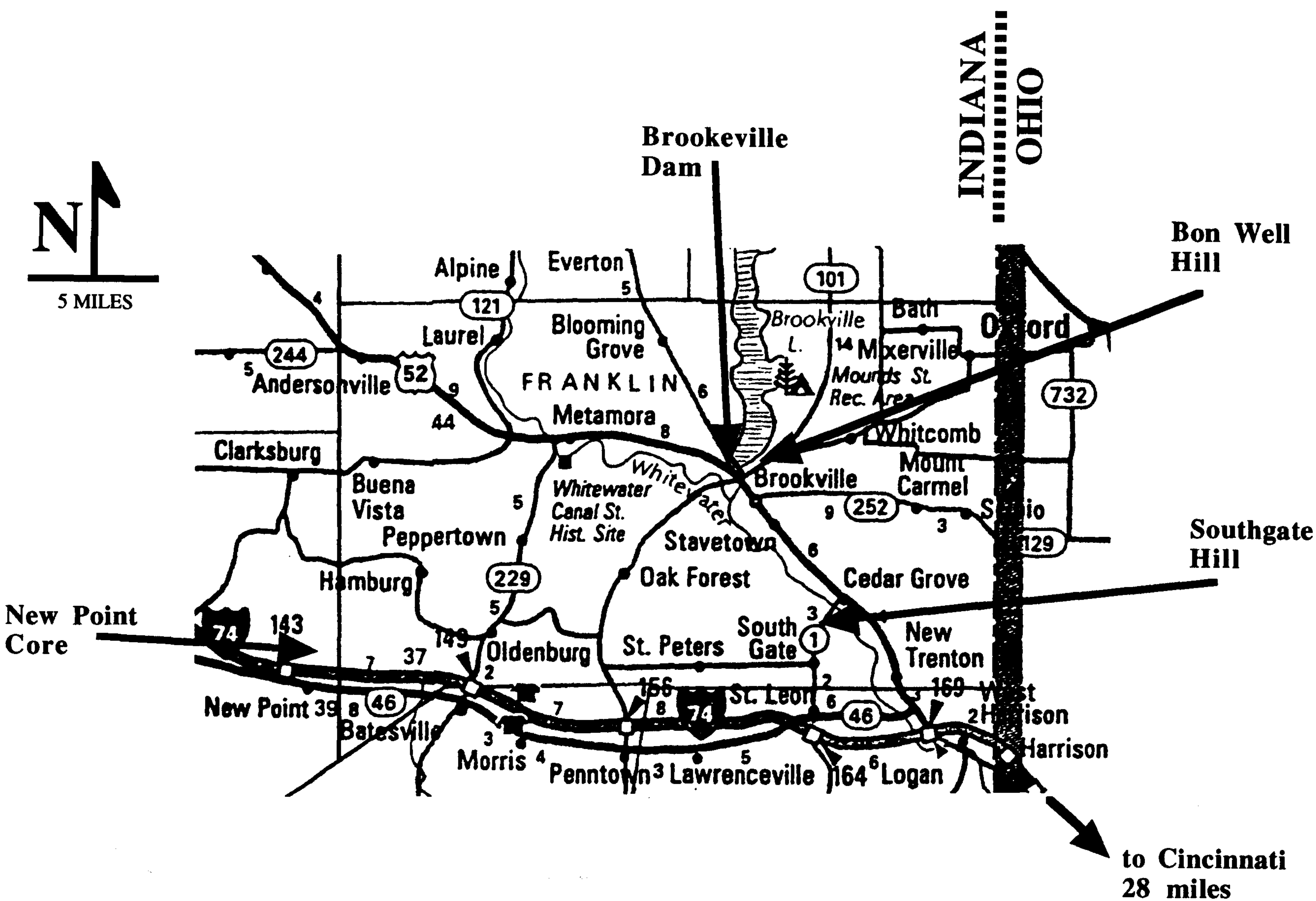

Figure 7: Locality Index Map, Franklin County, Indiana and surrounding area.

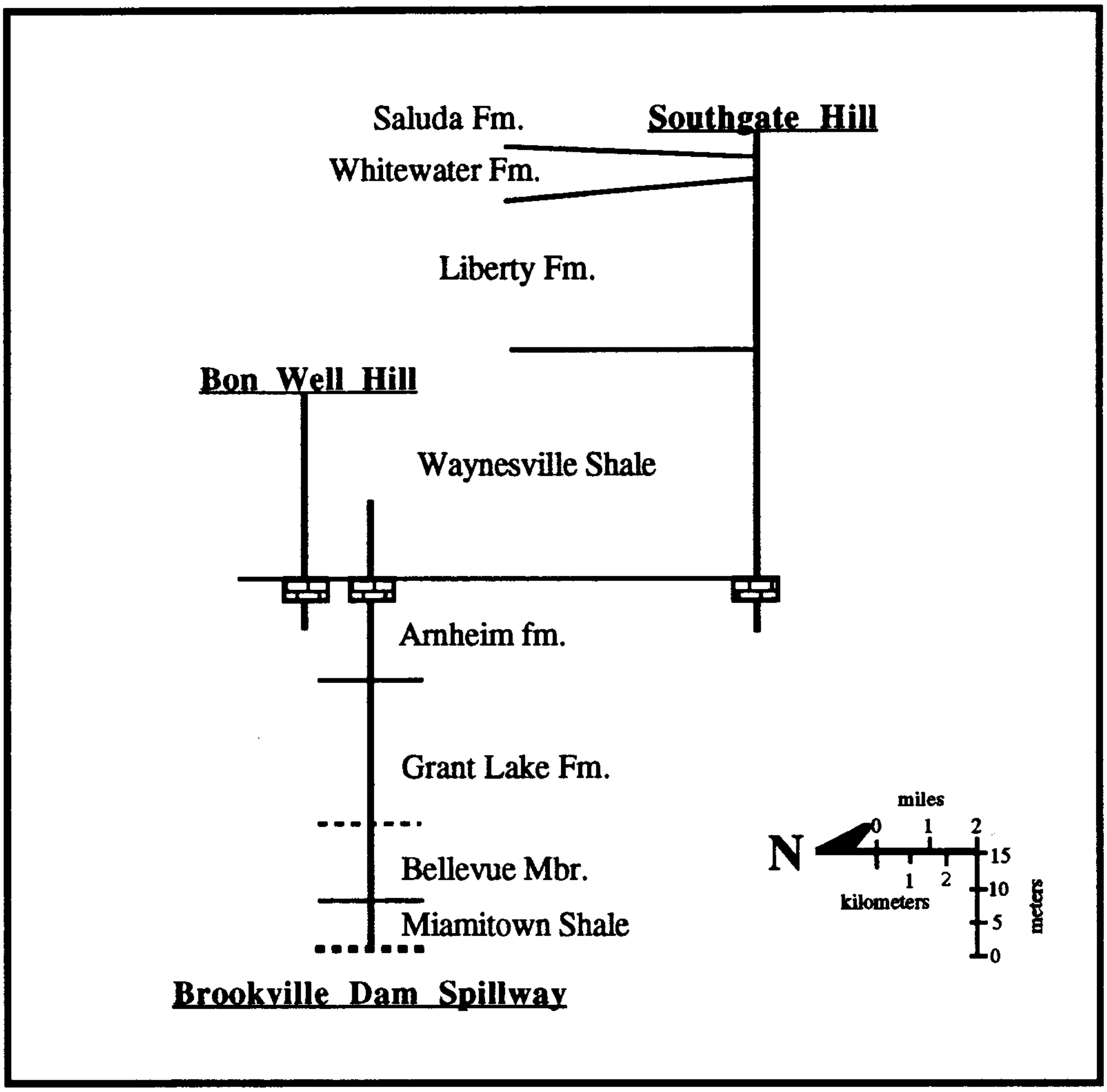

Figure 8: Waynesville Shale - Arnheim correlation of the Brookville area sections. Nomenclature after Schumacher (1993).

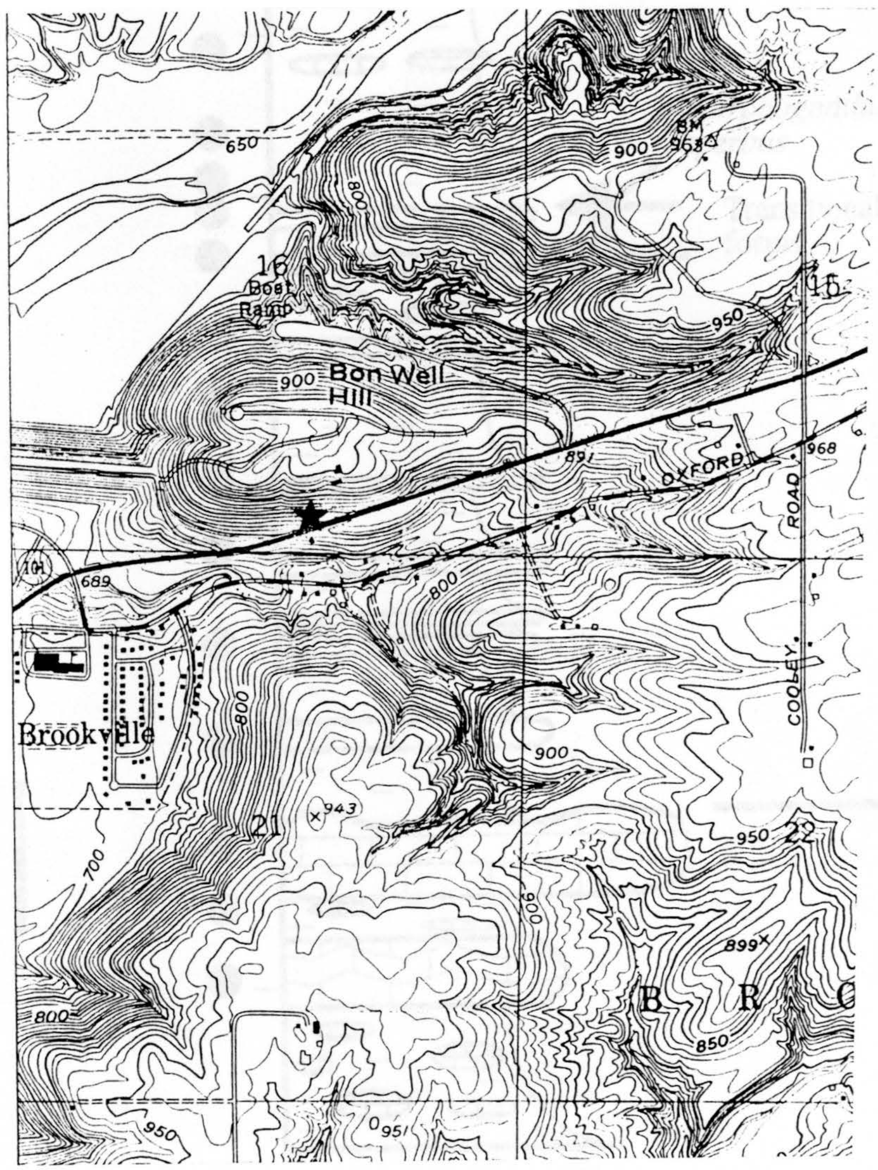

Figure 9: From the Whitcomb, Indiana Quadrangle. Bon Well Hill section denoted by the star.

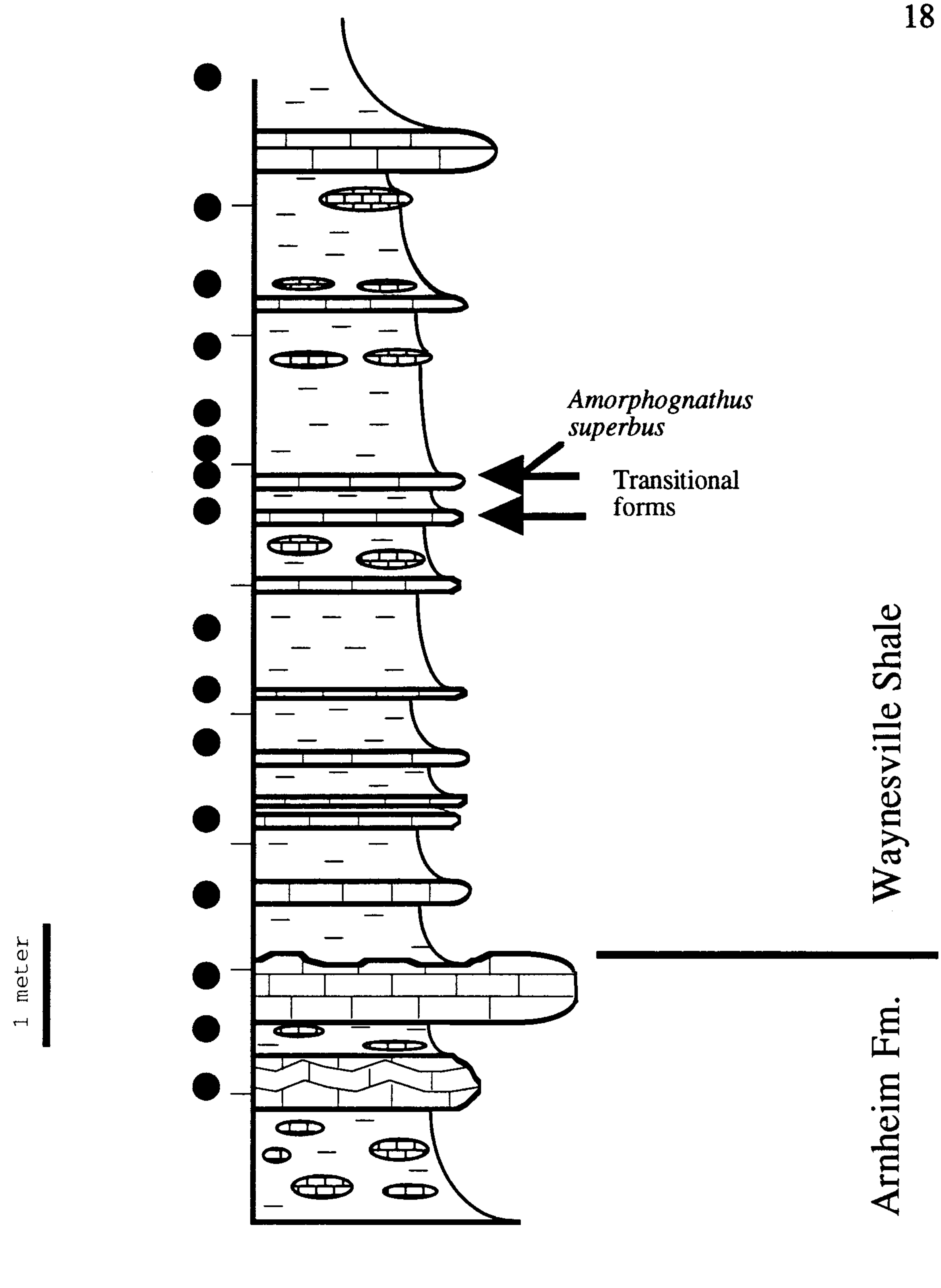

Figure 10: Bon Well Hill section and *Amorphognathus* M element occurrence. Spots indicate sample levels.

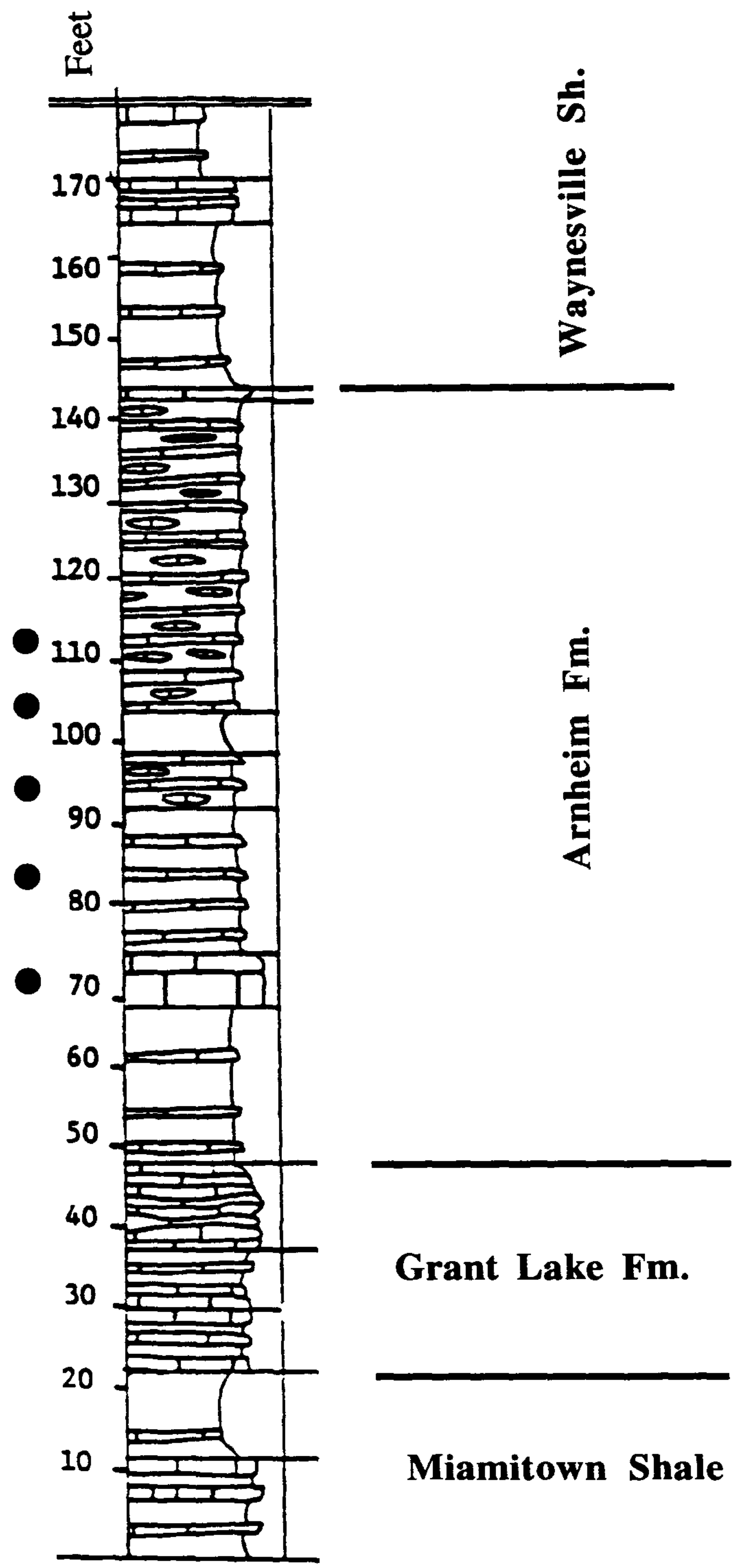

Figure 11: Brookeville Dam section (from Hay, 1993). Spots indicate sample levels.

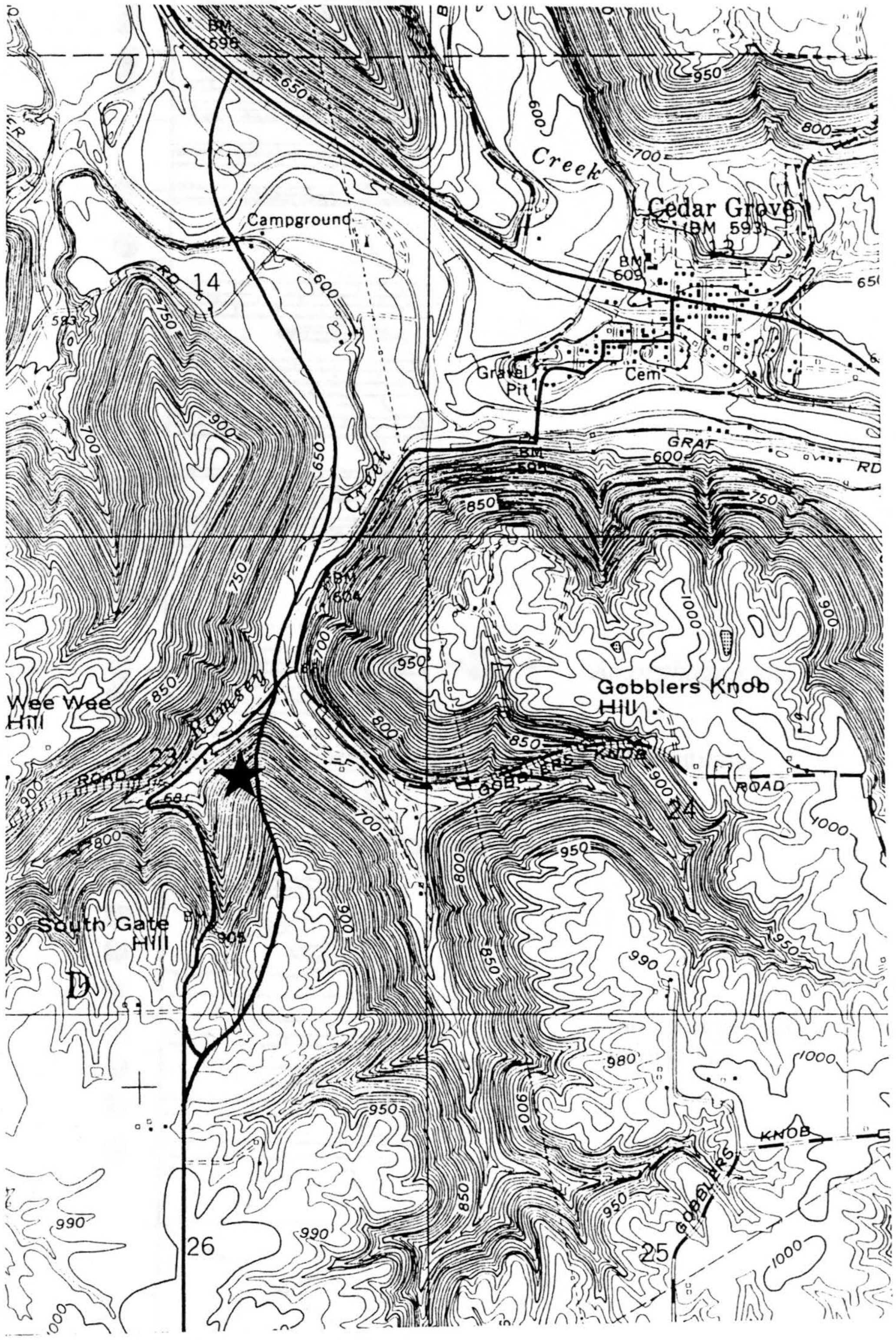

Figure 12: From the Cedar Grove, Indiana Quadrangle. Southgate Hill section is denoted by the star on the new road section marked on this map.

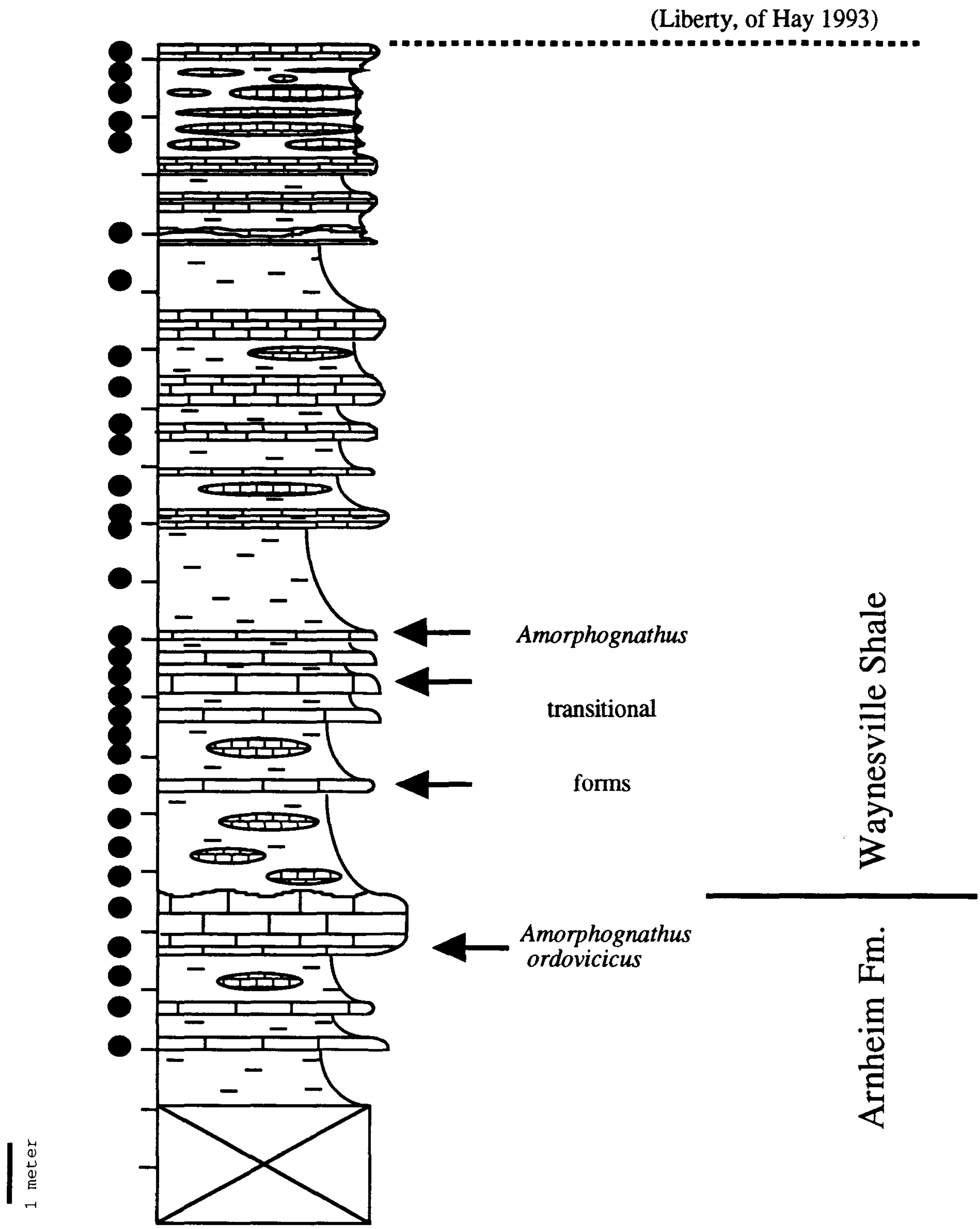

Figure 13: Southgate Hill section and *Amorphognathus* M element occurrence. Spots indicate sample levels.

METHODS OF STUDY

The major problem with trying to isolate *Amorphognathus* specimens from Cincinnatian rocks is that most of these strata represent a shallow water, carbonate shelf facies. *Amorphognathus* species are deeper or colder water forms that tend to be rare, or missing, in tropical shallow water facies. Sweet (1989; Fig. 14b) described a conodont biofacies model based on environmental differentiation of some conodont genera in the Cincinnati region. Based on his model, it appeared that in order to have any chance at isolating the zonally important *Amorphognathus ordovicicus* within the type Cincinnatian, a 'deeper water' lithofacies had to be investigated. Cincinnatian depositional depth appears to increase westward from western Ohio, and for this reason, the upper Cincinnatian outcrop area in southeastern Indiana was selected as the study area for this project. In particular, the early Richmondian Waynesville Shale was targeted for study as it seemed to represent the 'deepest' water facies available in the Maysvillian-Richmondian interval (see Figure 2).

Samples were collected from the three outcrops near Brookville, Indiana mentioned above (see Figure 7,8). Sampling intervals varied, as every limestone bed was sampled in addition to numerous shale intervals. Certain beds were resampled due to occurrences of elements of *Amorphognathus*. Sample sizes ranged from five to fifteen kilograms. All samples were processed using the standard conodont processing techniques outlined by Harris and Sweet (1989). After the rock had been crushed to approximately one-quarter inch pieces, in most cases two and a half kilograms of each sample were disaggregated in a ten percent solution of glacial acetic acid and washed through a 150 standard mesh sieve. Conodonts in the acid residues were further concentrated using the heavy liquid 1,1,2,2 tetrabromoethane (TBE). Conodonts of the TBE heavy residues were then further concentrated by removing the pyrite with MI-GEE brand methylene iodine and/or by removing magnetics with the Franz Isodynamic Magnetic Separator. The conodonts of the remaining residue were then picked and mounted on standard paleontological slides.

CONODONT BIOSTRATIGRAPHY

Depositional Environment

Conodont paleoecologic studies in the Cincinnatian were initiated by Bergström and Sweet (1966), who recognized that species of *Phragmodus* Branson & Mehl 1933 and *Plectodina* Stauffer 1935 characterize the Eastern Midcontinent Province. Further studies by Kohut and Sweet (1968) designed the area of common *Phragmodus* and *Plectodina* as that of a 'northern fauna' and that of dominating *Aphelognathus* Branson, Mehl & Branson 1951, *Oulodus* Branson & Mehl 1933, and *Rhipidognathus* Branson, Mehl & Branson 1951 as that of a 'southern fauna'. The lithic features of the southern fauna successions indicate a shallow water depositional environment. Barnes and Fåhraeus (1975) noted that the northern fauna was, by and large, associated with the lithic characteristics ascribed to relatively deeper water, *Plectodina* being present in rocks of moderate depth and *Phragmodus* in deeper water strata. Sweet (1988) proposed a conodont depth stratification model (Figure 14a). By applying the depth stratification model to the Cincinnatian, Sweet (1988) generated a biofacies scheme (Figure 14b) that has been applied to Middle to Upper Ordovician sections by several authors and is used herein (Figure 15a).

My collections show that *Plectodina* dominates the Arnheim conodont fauna whereas *Phragmodus* increases sharply in the lowermost Waynesville and becomes the dominant taxon. The relative abundance changes of *Plectodina* and *Phragmodus* across the Arnheim - Waynesville boundary supports the idea that a deepening event occurred during the deposition of the lowermost Waynesville Shale (Figure 15b). This provides direct support to the interpretation of many previous workers that the Arnheim represents a shoaling. Also, Holland (1993) identified the basal contact of the Waynesville Shale as a Maximum Flooding Surface and boundary for his C4 sequence (see Figure 2).

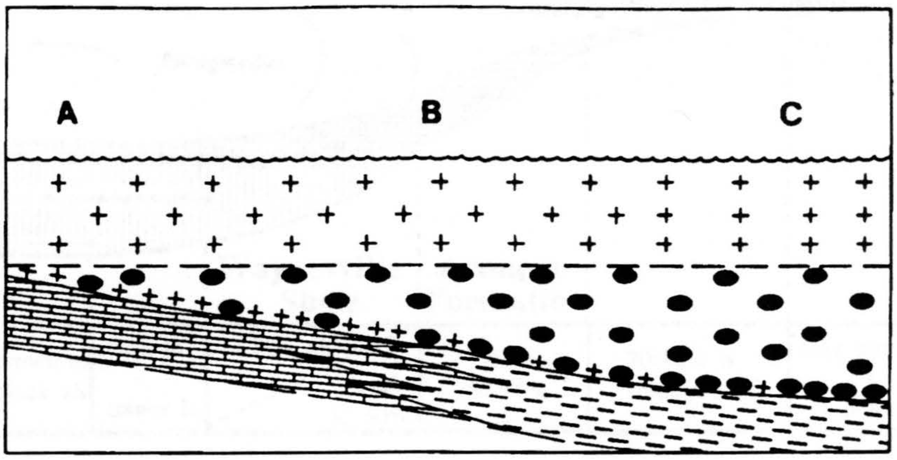

Figure 14a: Depth Stratification model of Seddon and Sweet (1971) from Sweet (1988). Crosses mark taxa living near the water surface; dots mark taxa living at greater depth.

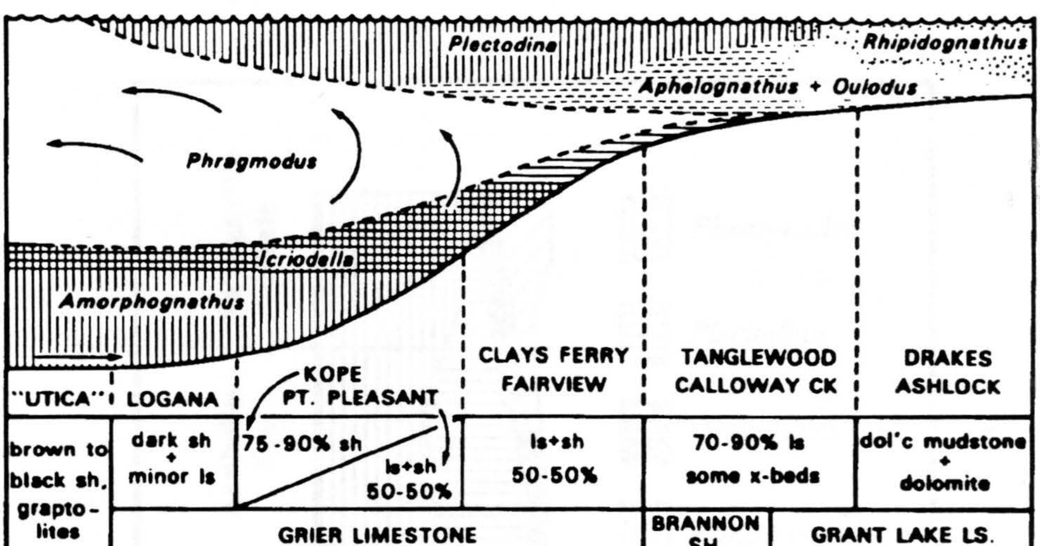

Figure 14b: Cincinnatian conodont biofacies model proposed by Sweet (1988).

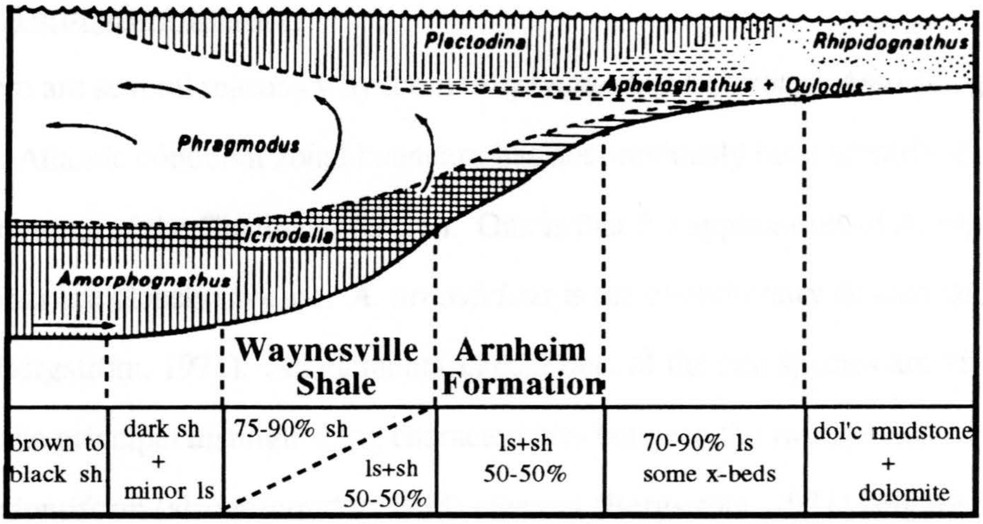

Figure 15a: Sweet's (1988) Cincinnatian biofacies model applied to the Upper Ordovician Waynesville Shale and Arnheim formation.

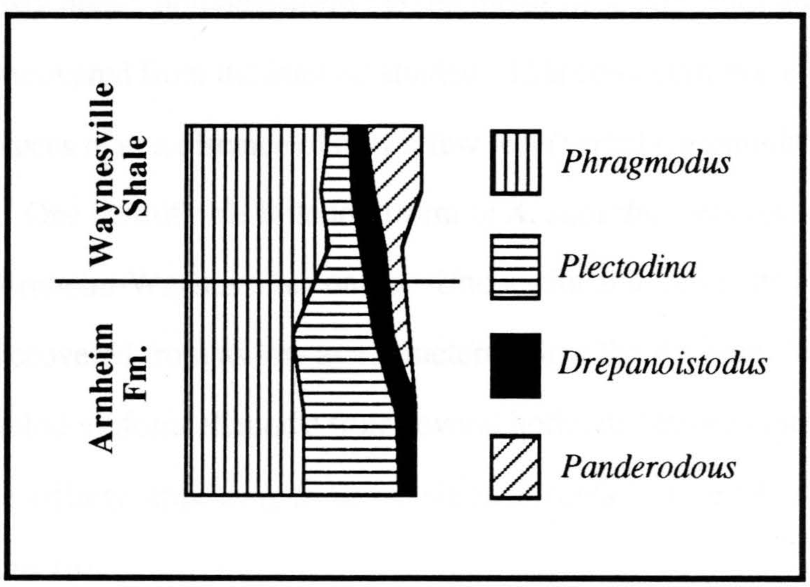

Figure 15b: Relative abundance log of dominant conodont genera across the Arnheim-Waynesville boundary (One meter above, 1.5m below) from the Southgate Hill section. For Sample levels see Figures 13 and 18)

Evolving *Amorphognathus*

There are several reasons why the *Amorphognathus superbus* - *Amorphognathus ordovicicus* Atlantic conodont zonal boundary has not previously been identified in the Upper Ordovician of the Cincinnati Region. One is that the apparatuses of *A. superbus* and *A. ordovicicus* are closely similar. *A. ordovicicus* is the evolutionary descendant of *A. superbus* (Bergström, 1971). All elements, except one, of the two species are virtually identical. The principal distinguishing characteristics between the two species are shown by the holodontiform (also referred to as M) element (Bergström, 1971) (Figure 16). Recovery of these holodontiform elements have historically proved elusive, but refinements in processing techniques have increased the success in finding them. The holodontiform elements are typically the smallest in the apparatus, and they are small enough that if one washes the sample through a sieve with larger than 150 size mesh, there is a good chance of washing them down the sink.

As previously noted, holodontiform (M) elements of *A. superbus* and *A. ordovicicus* were recovered from the interval studied. This co-occurrence is recognized in several other sequences over a distance of only a few feet (verbal communication from Bergström, 1993). One identifiable holodontiform of *A. superbus* was recovered from 3.8 meters above the Arnheim-Waynesville contact. Unquestionable elements of *A. ordovicicus* were recovered from as low as 1.2 meters below the Arnheim-Waynesville contact. Several holodontiform elements from several horizons between these occurrences are of questionable affinity, appearing to be transitional forms between *A. superbus* and *A. ordovicicus* (Figure 16).

Other faunal constituents are reported here only on an occurrence basis. Further studies on the distribution and frequencies of these forms in the Brookville sections are forthcoming. The other species found near the Arnheim Formation-Waynesville Shale boundary include: *Aphelognathus grandis* Branson, Mehl & Branson 1951,

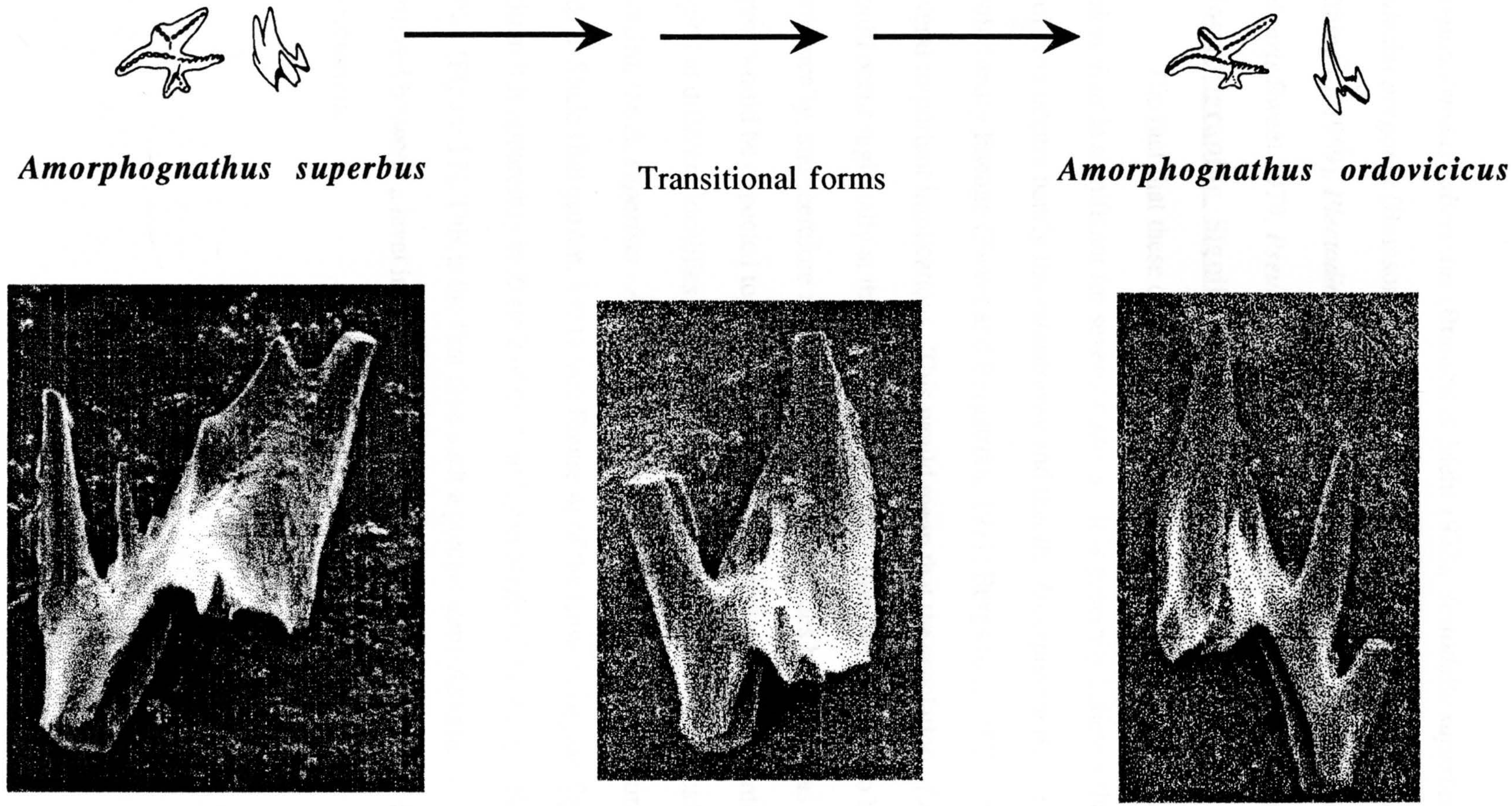

Figure 16: Scanned images of three morphotypes of *Amorphognathus* isolated from the Lower Richmondian of the Brookville area.

Drepanoistodus suberectus (Branson & Mehl 1933), *Icriodella superba* Rhodes 1953, *Oulodus oregonia* (Branson, Mehl & Branson 1951), *Panderodus* spp., *Periodon grandis* (Ethington 1959), *Plectodina tenuis* (Branson & Mehl 1933), *Pseudobelodina vulgaris vulgaris* Sweet 1979, *Pseudobelodina* sp., and *Rhodesognathus elegans* (Rhodes 1953).

Biostratigraphic Significance

The fact that these collections of *Amorphognathus* include both *A. superbus* and *A. ordovicicus* is significant for several reasons. It is generally believed that heterochronic evolution occurs nearly instantaneously and that the *Amorphognathus* series is indeed an evolutionary lineage (Sweet and Bergström, 1971; Bergström, 1971, 1983). This has several important implications. This would mean that the speciation of *A. ordovicicus* would occur regionally at the same time. The time involved is likely to be short geologically, and therefore an assemblage which includes both types, as well as transitional types, would be expected to be present in a very narrow stratigraphic interval that would be coeval at different localities, even at sites that are separated geographically. For instance, in Sweden, the *A. superbus - A. ordovicicus* evolutionary transition occurs in the uppermost Fjäcka Shale (Bergström, 1971) (see Figure 4) of the Lower Harjuan Series, and in Great Britain it is apparently in Zone 2 of the Cautleyan Stage of the Ashgill Series (Orchard, 1980) (Figure 17). This is the first time such a precise trans-Atlantic correlation has been achieved between a level in the Cincinnatian reference standard and key European successions.

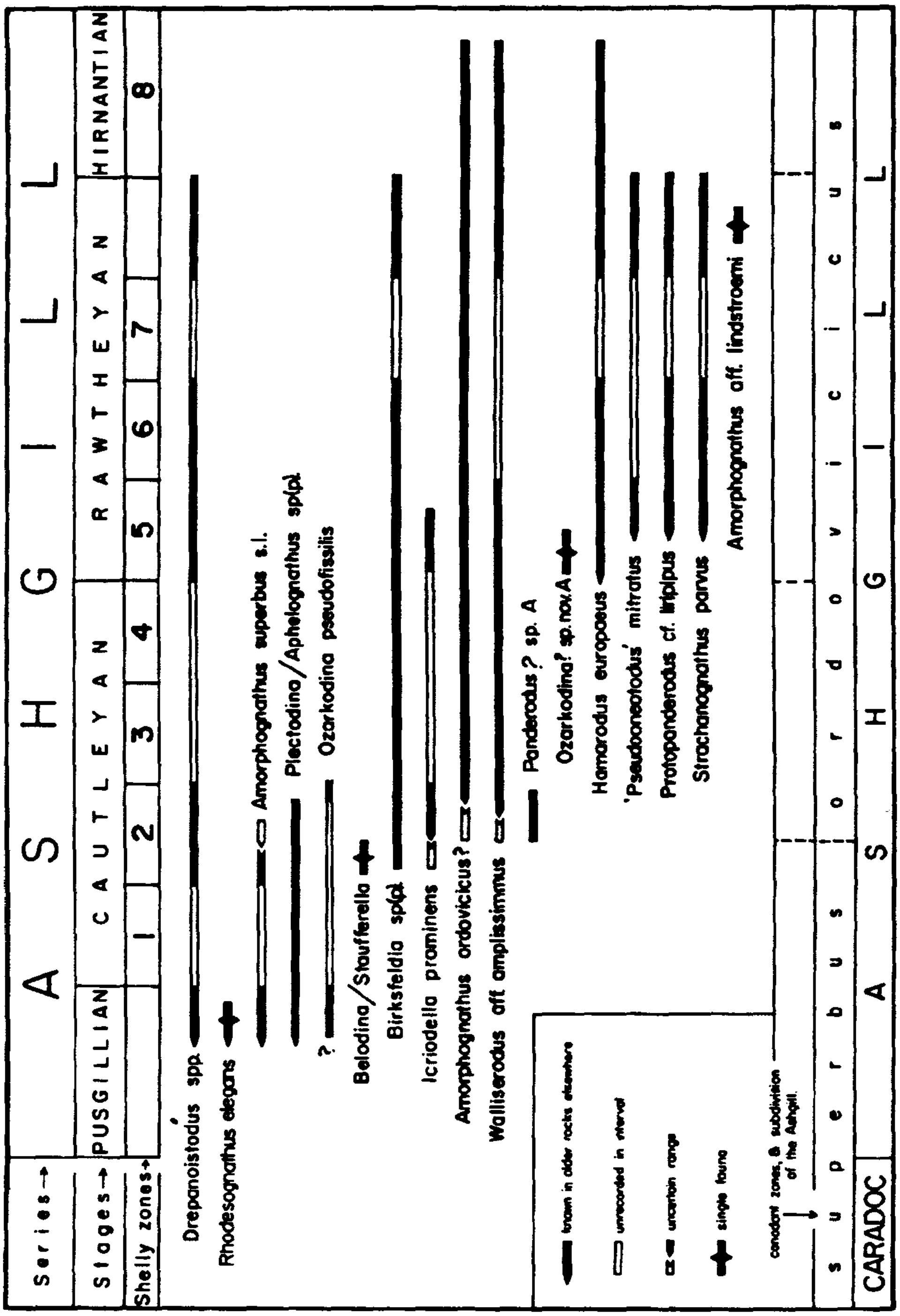

Figure 17: Northern England and Wales conodont ranges. From Orchard (1980).

CONCLUSIONS

Based on data collected during the course of the present study, the following conclusions can be drawn:

- Detailed collecting from the upper Arnheim Formation and lower Waynesville Shale in southeastern Indiana has revealed the presence of several previously unrecorded species of conodonts in the Richmondian of the Cincinnati region, including species of *Amorphognathus* and *Periodon.*
- *Amorphognathus* is a globally distributed, and stratigraphically highly significant genus. Species of *Amorphognathus* form a rapidly evolving evolutionary lineage (Bergström, 1983), the two youngest species of which are *A. superbus* and *A. ordovicicus.* The level of evolutionary transition between these two species has been used as the base of the North Atlantic Province *A. ordovicicus* zone (Bergström, 1971).
- In the studied sections in southeastern Indiana, there are, in a narrow stratigraphic interval, specimens typical of *A. superbus* and *A. ordovicicus* in addition to transitional morphotypes. This is interpreted as representing the time of the speciation event.
- Because the *A. superbus* and *A. ordovicicus* evolutionary transition occurs elsewhere (for instance, northwestern Europe) in a equally narrow interval, the level of appearance of typical *A. ordovicicus* in the uppermost Arnheim Formation, in the study area, is taken as the base of the *A. ordovicicus* Zone. It should be noted that the only species of *Amorphognathus* found thus far below the uppermost Arnheim Formation is *A. superbus.*
- The base of the *A. ordovicicus* Zone, as recognized herein, can be correlated across the Atlantic to sections in Baltoscandia and Great Britain (Figure 18). This is the first time such a narrowly defined level in the Cincinnatian has been recognized in European standard successions. Also, the recognition of the level of this zonal boundary in the lower Richmondian standard is highly significant for interpretation of the Late Ordovician depositional history across North America.

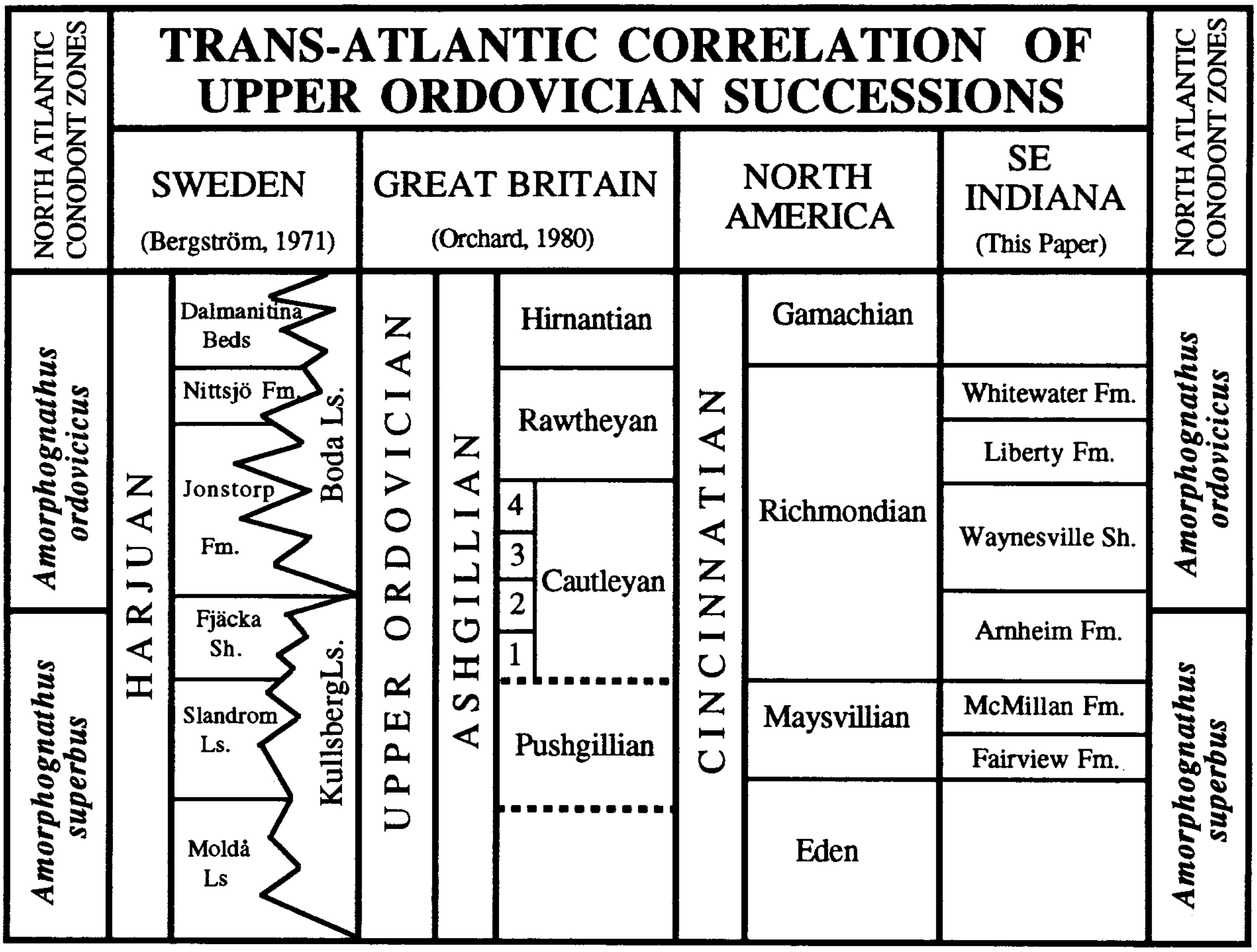

Figure 18: Proposed trans-Atlantic correlation for the studied interval with Baltoscandia and Great Britain.

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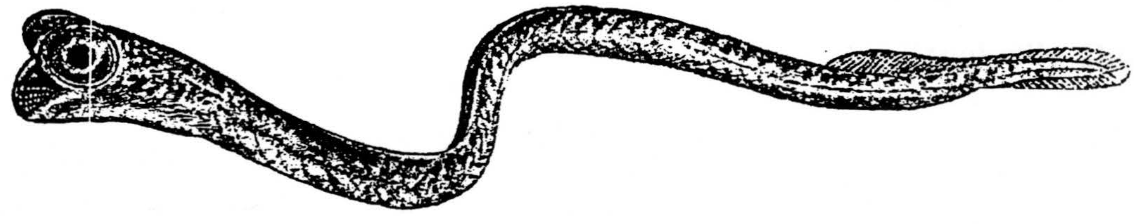

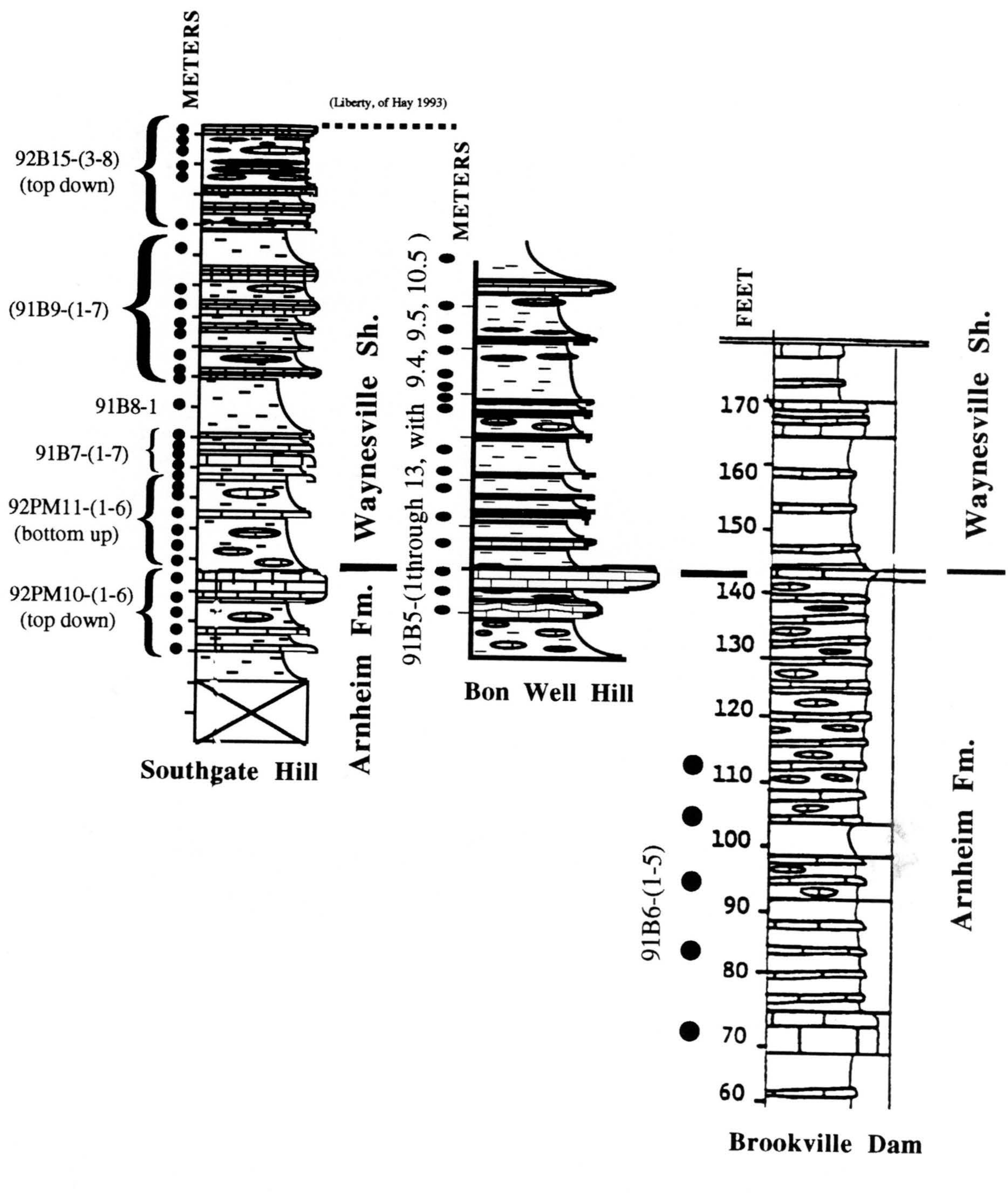

APPENDIX FIGURE: Sample numbers from the Brookville area sections.

PLATE 1

1,3 **Amorphognathus superbus** (Rhodes 1953);
- 1. 'Typical' holodontiform (M) element from Iowa for comparison (x210).
- 3. holodontiform (M) element, from the Richmondian (91B5-10)(x210).

2,6-8 **Amorphognathus ordovicicus** Branson and Mehl 1933;
- 2. 'Typical holodontiform (M) element from Iowa for comparison (x210).
- 6-8. holodontiform (M elements), from the Richmondian.
  - 6. (92PM10-1) x150.
  - 7. (91B7-5) x185.

4,5 **Amorphognathus sp. aff. A. ordovicicus** Branson and Mehl 1933;
- 4. (91B7-5) x210.
- 5. (91B5-10) x220.

9-14 **Amorphognathus spp.** Branson and Mehl 1933;
- 9. Pa element (92PM10-2) x120.
- 10. Pb element (91B7-1) x168.
- 11. Pb element (91B7-1) x170.
- 12. Sd element (92PM10-2) x160.
- 13. Sc element (91B7-5) x185.
- 14. Sb element (91B7-5) x215.

15,16 **Aphelognathus grandis** Branson, Mehl & Branson 1951
- 15. Sa element (92PM11-2) x65.
- 16. Pa element (92PM11-2) x62.

17 **Periodon grandis** (Ethington 1959); (91B7-4) x143.

18-20 **Rhodsognathus elegans** (Rhodes 1953); (91B7-1) x155, x165, x125.

21,22 **Icriodella superba** Rhodes 1953; (91B6-3) x150, x205.

PLATE 2

1-3 **Drepanoistodus suberectus** (Branson and Mehl 1933);
1. homocurvatiform element x110.
2. suberectiform element x130.
3. inclinatiform element x115.

(all specimens are from 92PM11-2)

4,8 **Panderodus spp.** Ethington 1959 (92PM11-2) x160, x130.

5-7,9,10 **Pseudobelodina spp.** Sweet 1979 (92PM11-2) x220, x110, x110, x180, x180.

11-16, 23 **Phragmodus undatus** Branson and Mehl 1933;
11. M element x120.
12. Sa element x156.
13. Sc element x120.
14. Sb element x130.
15. Pb element x150.
16. Pa element x115.

(all specimens above from 92PM11-2)

23. Sb element with basal funnel preserved. (91B7-5) x60.

17-22 **Plectodina tenuis** (Branson and Mehl 1933);
17. Pa element x75.
18. Pb element x78.
19. Sc element x65.
20. Sb element x75.
21. Sa element x70.
22. M element x60.

(all specimens from 92PM11-2)

24 **Oulodus oregonia** (Branson, Mehl and Branson, 1951) (92PM11-2) x90.

PLATE 1

PLATE 2